THE EFFECT OF NEUROPHIL DRUGS ON THE FIDDLER CRAB, *UCA PUGNAX*.

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These experiments were made to determine if the fiddler crab, *Uca pugnax* S. I. Smith, could be forced to move in only one direction, rather than sidewise, forward and backward, by means of the effect of a suitable drug. If this could be accomplished it would simplify the study of the phototropism of this animal. A drug that causes the legs on the opposite sides to pull against each other, such as nicotine, phenol, or veratrine, leads inevitably to movement backward, because the second pair of legs slopes backward at an angle of about 35°, the third pair also slopes backward at an angle of about 65°, the fourth pair remains almost vertical and the fifth pair of legs slopes forward at an angle of about 70°. This movement resulting from the more effectively braced second and third pair of legs opposing the fifth pair of legs is too irregular to produce a dynamic orientation.

The responses of the fiddler crabs to the neurophil drugs used may be compared with the results with other animals obtained by other investigators. The solutions were made by dissolving the alkaloid in 200 cc. of sea water in a finger bowl, which amount was sufficient to cover the animals. The control animals were placed in the same amount of sea water. Two animals were placed in each solution and from 2 to 5 separate experiments were performed on different days. Unless otherwise specified the solutions were all of 1 : 1,000 strength. During the time of observation the animal was placed in a large crystallizing dish containing an even layer of moist sand, after which it was returned to the solution.

Atropine SO_4 (1 : 500 to 1 : 10,000), apomorphine (sat. sol.), morphine SO_4, caffeine, codeine and digitonin were without any visible effect on the animals during 40 hours' exposure.

When an object is brought near a control *Uca* placed in the observation dish, the animal raises its large cheliped above its head, toward the stimulating object, and backs away from it. This response is inhibited after 5 min. immersion in picrotoxin (sat. sol.), 10 min. in strychnine SO_4, 15 min. in phenol or pilocarpine HCl and somewhat later in nicotine. Even when vigorously stimulated the animal cannot raise the chela. Conversely this response is greatly exaggerated after 3–4 minutes in camphor; the animal now does not back away but will grab a pencil or other object in its big claw and will hold it more firmly, and for a longer time than the control animal can be induced to do after the control animal has been "cornered" at the edge of the dish.

Picrotoxin, phenol, and veratrine (sat. sol. alkaloid) reverse the usual activity of the legs so that the legs on the opposite sides of the body pull against each other rather than moving together, as has been mentioned. An analysis at the locus of this effect might perhaps be made with the aid of a galvanic current as has been done with *Lineus*.[1]

All of the legs except the chelipeds are drawn upward and toward the body by contraction of the dorsal musculature of the legs (opisthotonic) after 1/2 hour's immersion in strychnine SO_4, phenol or camphor. The strychninized animal's body rests in the sand when the legs are drawn up but the animal can move on stimulation in any direction. This would seem to result from a partial paralysis of parts of the neuromuscular system rather than a specific effect on synapses. Nicotine, veratrine and pilocarpine HCl cause the legs to be extended. In nicotine and in picrotoxin the legs are first extended and later those of the opposite sides are drawn together, so that the animal instead of being held only a few millimeters from the sand is raised up 8/10 mm. above the substratum. After several hours in phenol the legs are drawn together toward the center of the body but the distal segments of the legs are not extended.

Very little asymmetric behavior of the unequal chelipeds of the animals was observed. The male crabs after veratrinization tend to move sidewise in the direction of the large chela. The

[1] See Crozier[7]; *cf.* also Kropp, B., and W. J. Crozier, 1928. Jour. Gen. Physiol., 12: 111–22.

legs were drawn more closely toward the body on the side opposite the large chela as this phase of the picrotoxin effect appeared. The chief difference noticed was that when this large chela was prevented from being drawn close to the body the animals were unable to right themselves after falling on their backs.

Camphor and to a lesser extent nicotine seem to lower the threshold of excitation and the animals are more active than the control animals. The same drugs also affect the chromatophores, so that the animals become lighter in color and after an hour are a light blue. This coloration persists for some time after apparent death.

The reversal of the response of the large claw by strychnine in *Uca* resembles a similar reversal of the response of the prolegs of caterpillars found by Crozier [2] to result from the injection of atropine. Camphor excites the fiddler crab but inhibits in the grasshopper.[3] The specific effect of camphor in determining the backward swimming of *Crangon* [4] is not parallel with *Uca*. Backward movements of the crayfish are impeded by strychnine,[2] but this drug has no such effect on the fiddler crab. The effect of strychnine and nicotine on the legs of the fiddler crab is comparable to the effect of these drugs reported by Moore,[5] who found that strychnine causes the arms of *Asterias* to bend dorsally while nicotine forces the arms to bend ventrally.

The responses of *Uca* to strychnine, picrotoxin, nicotine, camphor, and phenol, but not to atropine or caffeine, indicate that the crab neuromuscular system is more like that of the insects than like that of the worms.[6, 7] An isopod, *Asellus*, is unaffected by strychnine, caffeine, atropine, and nicotine[8]. The greater alkalinity of sea water may be more favorable to a combination of the alkaloids with the tissue proteins, as has been suggested by the experiments of the Petrunkins,[9] and may

[2] Crozier, W. J., 1922. Biol. Bull., 43: 239–45.

[3] Crozier, W. J., and G. F. Pilze, 1924. Amer. Jour. Physiol., 69: 41–2.

[4] Moore, A. R., 1917. Proc. Nat. Acad. Sci., 3: 598–602.

[5] Moore, A. R., 1920. Jour. Gen. Physiol., 2: 201–4.

[6] Moore, A. R., 1921. Jour. Gen. Physiol., 4: 29–31.

[7] Crozier, W. J., 1927. Jour. Gen. Physiol., 10: 395–406.

[8] Fries, E. F. B., 1928. Jour. Gen. Physiol., 11: 507–13.

[9] Petrunkin, A., and M. Petrunkin, 1927. Jour. Gen. Physiol., 11: 101–10. *Cf.* also Crozier [2].

account for the different effects on the fresh water and marine arthropods. Since the crab is not affected by caffeine it may have a less differentiated nervous system than the squid.[6]

Summary.

A reversal of the usual motor responses of the legs of the male fiddler crab, *Uca pugnax*, has been observed when the animals have been in solutions of picrotoxin, strychnine, phenol, philocarpine, or veratrine in sea water. Camphor increases the irritability of the animals. Atropine, apomorphine, morphine, codeine, caffeine, and digitonin are without effect on the crabs. The results of these experiments are discussed in relation to those made with other arthropods.